

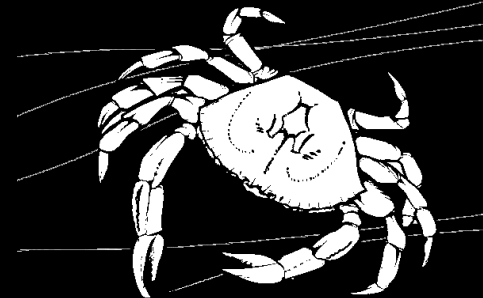
# Boundary Bay Ambient Monitoring Program Design

Presented to  
Boundary Bay Partners  
by  
ENKON Environmental Limited



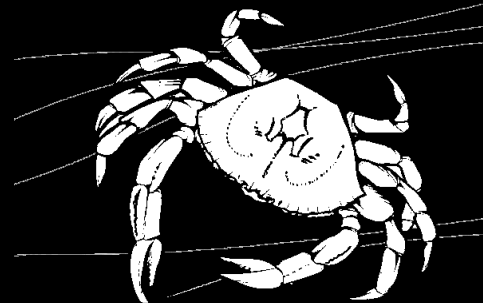
# Ambient Monitoring

Measuring conditions in the immediate environment surrounding but not directly affected by any discharge



# Potential Effects on Boundary Bay Environment

- Discharges:
  - Stormwater Runoff
  - Agricultural Runoff
  - Possible Input from Blaine WWTP
- Environmental issues:
  - Shellfish harvesting closures
  - Otherwise, environmental quality meets BC objectives





# Discharges to Boundary Bay





# BC Site Specific Environmental Quality Objectives for Boundary Bay

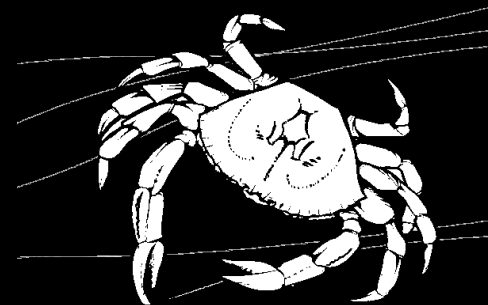
Parameter	Objective
Fecal coliforms	$\leq 200$ MPN/100 mL as a geometric mean from April to October $\leq 400$ MPN/100 mL as a 90th percentile from April to October
	$\leq 14$ MPN/100 mL as a median year round (long-term objective) $\leq 43$ MPN/100 mL as a 90th percentile year round (long-term objective)
Suspended solids	10 mg/L maximum increase when upstream values are $\leq 100$ mg/L 10% maximum increase when upstream values exceed 100 mg/L
Turbidity	5 NTU maximum increase when upstream values are $\leq 50$ NTU 10% maximum increase when upstream values exceed 50 NTU
Dissolved oxygen	6.5 mg/L minimum 9.0 mg/L minimum as a long-term objective
PCBs	0.03 $\mu\text{g/g}$ dry weight maximum in bottom surface sediments

PCBs means the sum of Aroclor 1242, 1254 and 1260.

Designated uses are aquatic life, wildlife and primary-contact recreation.

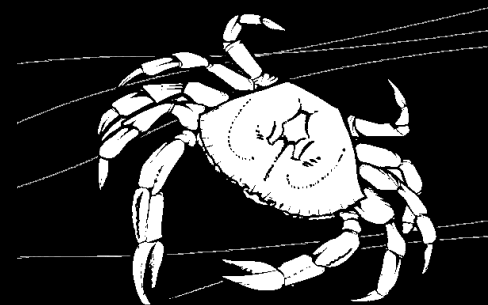
# Ambient Monitoring Program Objectives

- Provide a “baseline” of current environmental conditions in Boundary Bay
- Evaluate long term temporal trends in environmental quality
- Demonstrate whether programs to improve environmental quality are effective
- Integrate with other monitoring programs



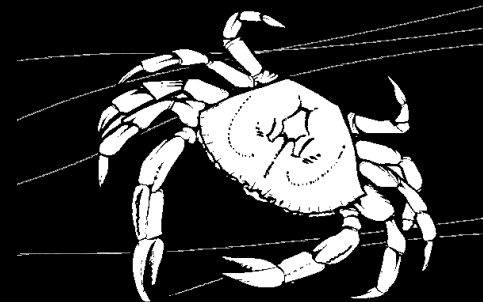
# Monitoring Program Requirements

- Components and indicators should be consistent with other Metro Vancouver ambient monitoring programs
- Indicators must be appropriate for the specific conditions in Boundary Bay



# Metro Vancouver Ambient Monitoring Programs

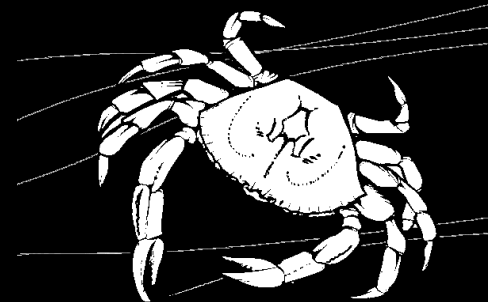
- Fraser River
- Burrard Inlet
- Georgia Strait





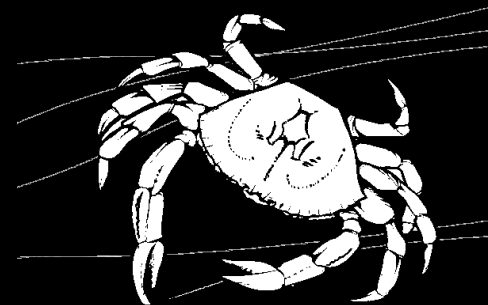
# Unique Features of Boundary Bay (Design Challenges)

- Shallow water/large intertidal area – access limitations, affects species distributions
- Sandy sediment – not all areas appropriate for sediment chemistry
- Both marine and estuarine areas – affects species distributions, water quality
- Relatively small study area – may be difficult to show regional differences in fish health or tissue contaminants



# Monitoring Program Components

- Common features of Metro Vancouver ambient programs (should include in design):
  - Water quality (physical, chemical & microbiological characteristics)
  - Sediment quality (physical, chemical & microbiological characteristics)
  - Fish health and tissue contaminants
- Other (to consider)
  - Benthic invertebrate community

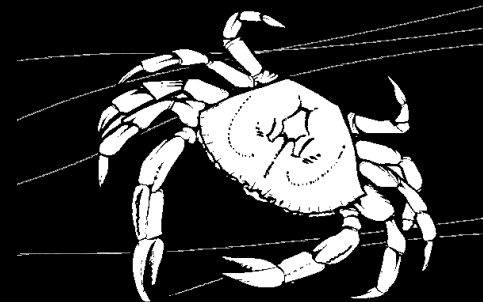


# Sampling Site Selection



# Site Selection Criteria

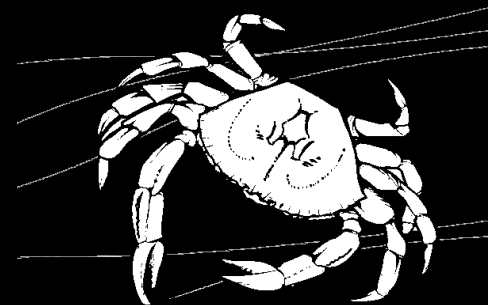
- Sites must not be influenced by any discharge.
- Sites must represent different areas of Boundary Bay.
- Locations with a previous history of monitoring are desirable.
- Biota and sediment sampling sites should have similar environmental characteristics to the extent possible.
- Sampling should not damage the environment (e.g. *Zostera marina* eelgrass beds).



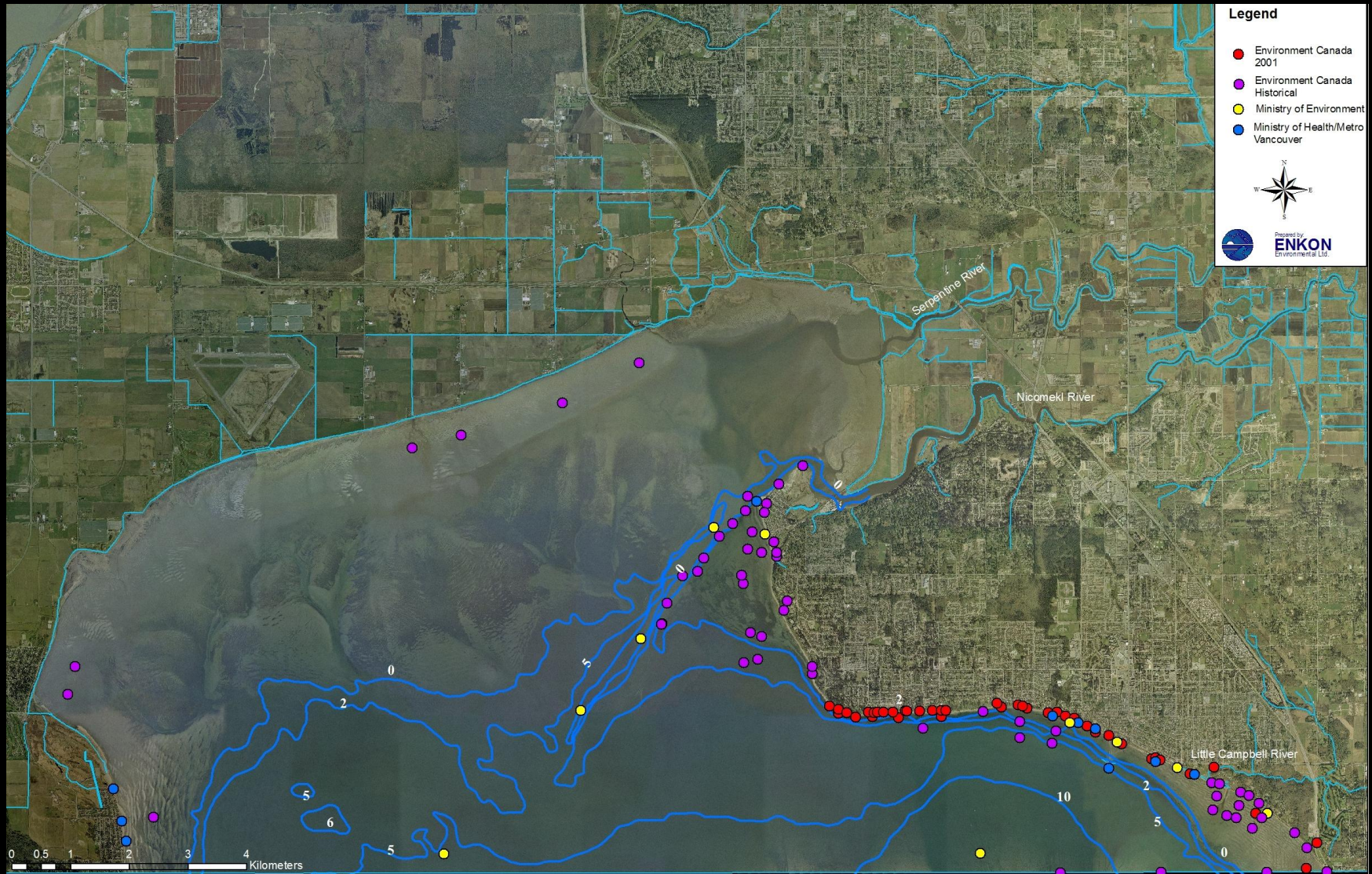


# Previous Studies

- Historical Environment Canada monitoring of fecal coliform related to shellfish harvesting (1970's)
- Coliform survey by Environment Canada (2001)
- Metro and Ministry of Health sampling (beaches)
- MoE water quality monitoring (1970's & 80's, occasional in 1990's & 2000's)
- MoE sediment & biota (tissue) sampling (1989, 1993, 2002)
- CWS benthic invertebrate survey (intertidal, circa 2000)

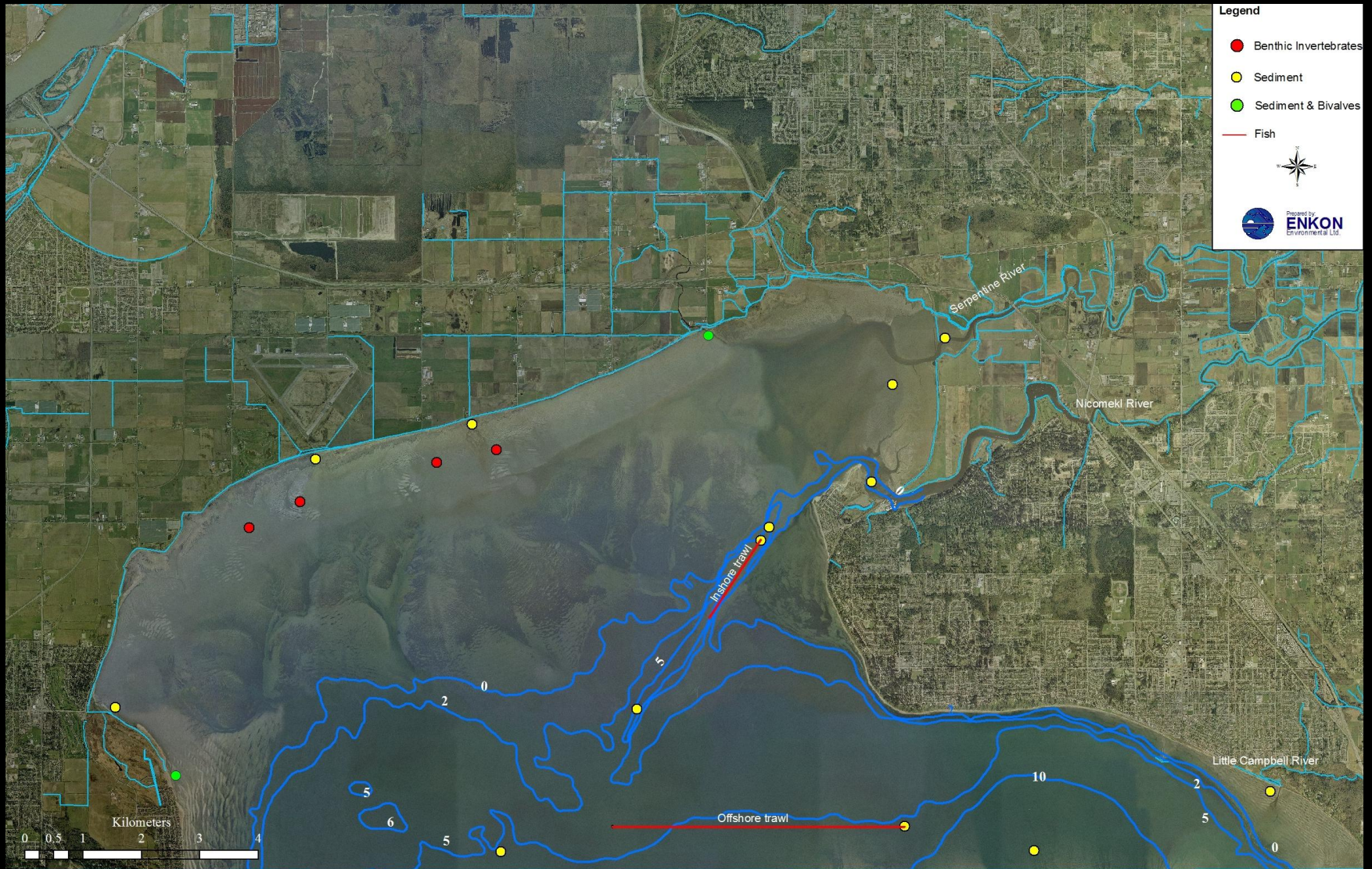


# Previous Water Sampling Sites



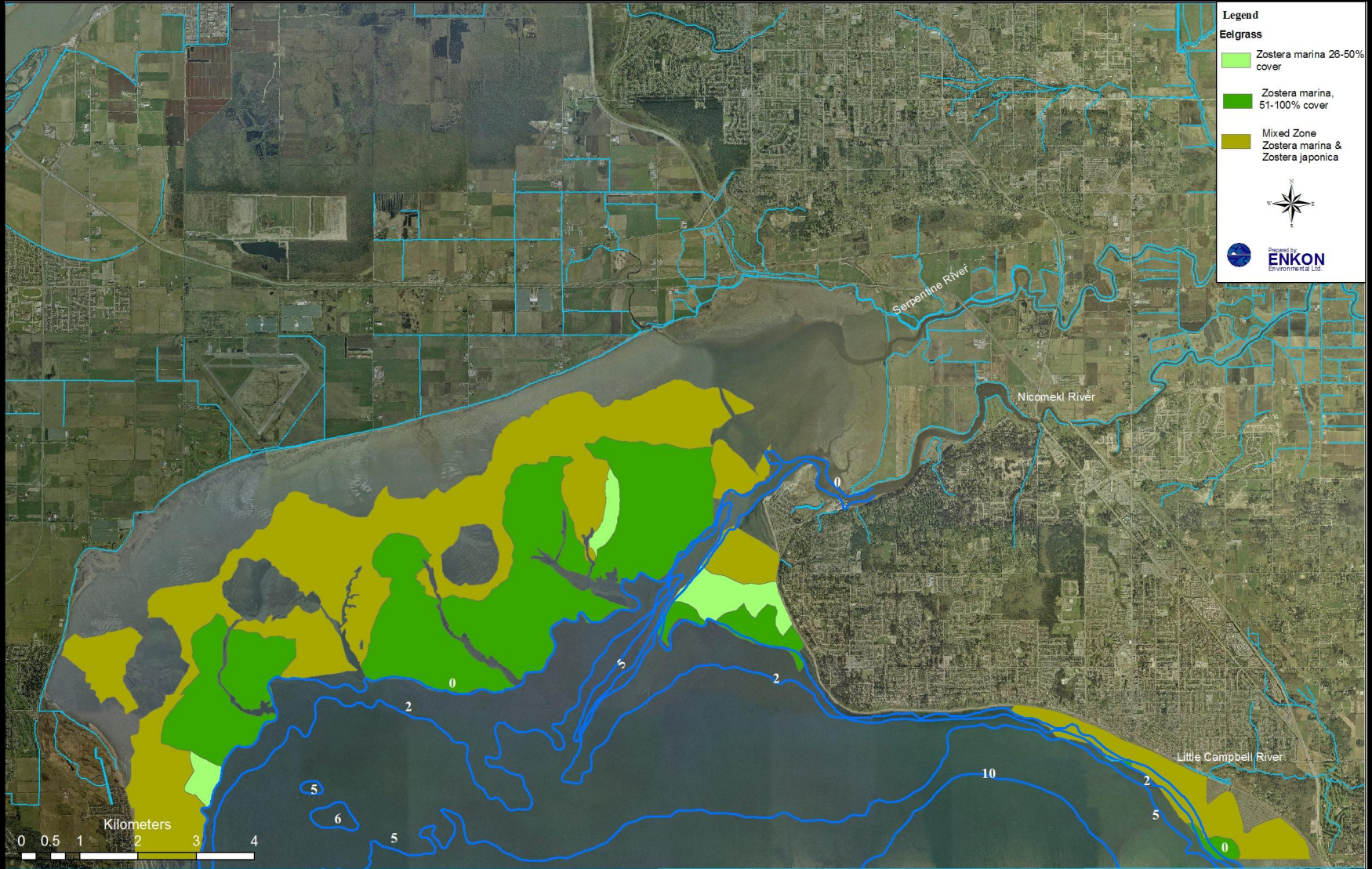


# Previous Sediment & Biota Sampling Sites





# Locations of Eelgrass Beds

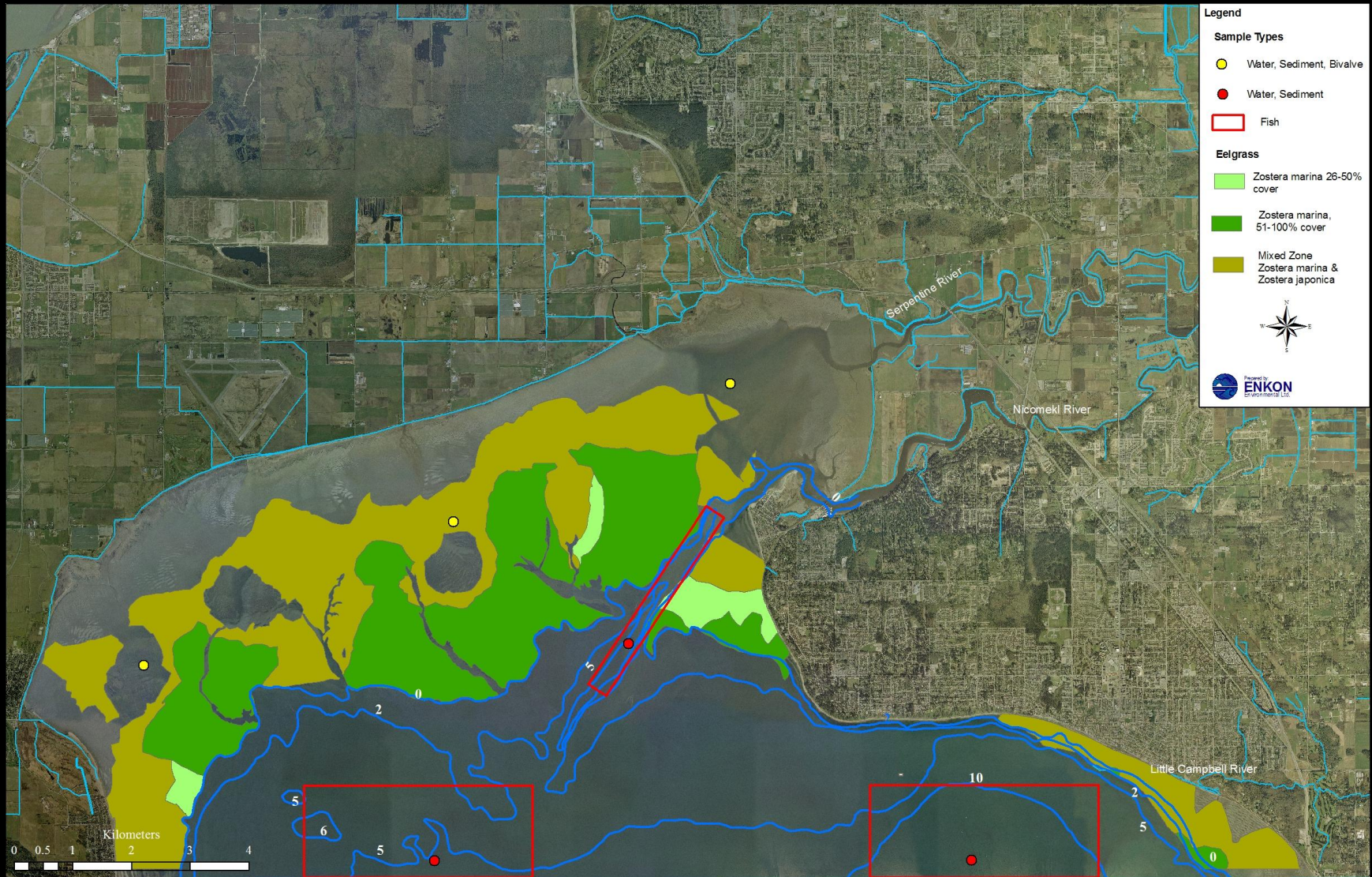




# Recommended Sampling Design

- Two sets of sampling sites to characterize entire Bay: subtidal & intertidal
- Sites approximately 5 km apart
- Appropriate indicators for each type of site (subtidal & intertidal)
- Will need to refine sampling locations in the field

# Recommended Sampling Sites



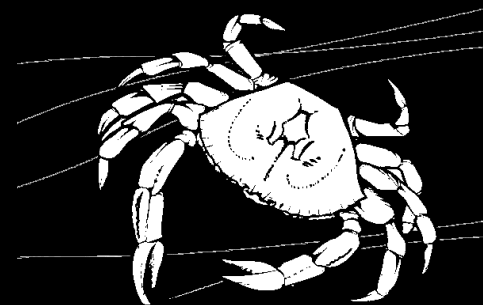


# Water Column Component Potential Parameters



# Parameter Selection Criteria

- Included in other Metro Vancouver ambient monitoring program(s)
- Existing BC objective for Boundary Bay or BC or federal (CCME) guideline or US EPA Region 10 criterion
- Other contaminants specific to Boundary Bay





# Potential Water Column Parameters

Parameter	Monitoring Program	Objective or Guideline	Rationale
pH	F,B		General Water Quality
Conductivity/Salinity	F,B		General Water Quality
Turbidity	F,B	BB Objective	General Water Quality
Dissolved Oxygen	F,B	BB Objective	Could be affected by stormwater
Temperature	F,B		General Water Quality
Total Suspended Solids	F,B	BB Objective	Present in stormwater
Total Dissolved Solids	F		Not useful for seawater
Chloride	F,B		Not useful for seawater
Silica	[F,B]		
<i>E. coli</i>	F,B	BC Approved	Present in stormwater Shellfish closures
Fecal Coliform	F,B	BB Objective	Present in stormwater Shellfish closures
Enterococci	B	BC Approved	Present in stormwater Recreational WQ

F – Fraser River, B – Burrard Inlet

[ ] - Not in original program; added to program at partner's request

# Potential Water Column Parameters (Continued)

Parameter	Monitoring Program	Objective or Guideline	Rationale
Nitrogen Species	F,B	BC Approved	Nutrient: eutrophication
Total Phosphorus	F,B		Nutrient: eutrophication
Chlorophyll a & Phaeopigments	[B]		Response to Eutrophication
Total Organic Carbon	B		Present in agricultural runoff, oxygen demand
Dissolved Organic Carbon	B		
Total Metals	F,B	BC Approved	Toxicity/Present in stormwater
Dissolved Metals	[F]		
PAH	--	BC Approved	Difficult to detect in water
Total Oil & Grease	[B]		Present in stormwater
Phenols	[B]		Unlikely in Boundary Bay
MBAS Surfactants	B		Lions Gate WWTP issue
Nonylphenol, Octylphenol & NPEOs	F,B	CCME/ BC Working	Present in wastewater, possibly in agricultural runoff

F – Fraser River, B – Burrard Inlet

[ ] - Analyzed but not necessarily recommended for ongoing monitoring or added at partner's request

# Recommended Water Parameters

pH  
Conductivity/Salinity  
Turbidity  
Dissolved Oxygen  
Temperature  
Total Suspended Solids

Fecal Coliform, *E. coli*  
Enterococci  
Nitrogen Species  
Total Phosphorus  
Total Metals

# Recommended Water Parameters

(Analyze if budget available)

Chlorophyll a &  
phaeopigments

Total organic carbon

Dissolved organic carbon

Dissolved metals

Nonylphenol &  
nonylphenoethoxylates

Silica

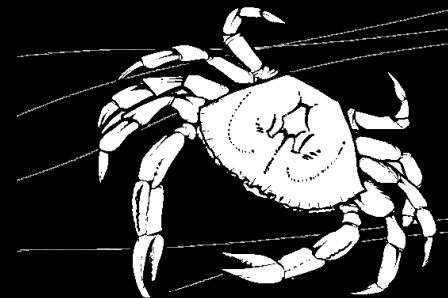


# Sediment Component Potential Parameters



# Parameter Selection Criteria

- Same criteria as for water quality parameters:
  - Included in other Metro Vancouver ambient monitoring program(s)
  - Existing BC objective for Boundary Bay or BC or federal (CCME) guideline or US EPA Region 10 criterion
  - Other contaminants specific to Boundary Bay



# Potential Sediment Parameters

Parameter	Monitoring Program	Objective or Guideline	Rationale
Particle Size	F,B	--	Affects contaminant accumulation
Moisture	B	--	General sediment characteristic
pH	B	--	General sediment characteristic
Total Volatile Solids	F	--	General sediment characteristic
Total Sulphide	F,B	--	General sediment characteristic
Total Organic Carbon	F,B	--	Moderates organics toxicity
Total Inorganic Carbon	[F]	--	General sediment characteristic
Total Organic Nitrogen	B	--	General sediment characteristic
Fecal Coliforms	F,B	--	Marker for wastewater, agricultural runoff, stormwater
Total Metals	F,B	CCME/BC Working	Toxicity/Present in stormwater
AVS & SEM	[F],B	--	Moderates metal toxicity
Polycyclic Aromatic Hydrocarbons	F,B	BC Approved	Toxicity/Present in stormwater
Alkylated PAHs	[F],B	*	Measured in other ambient monitoring programs

F – Fraser River, B – Burrard Inlet

[ ] - Analyzed but not necessarily recommended for ongoing monitoring

\* - Working guideline for 2-methyl naphthalene

# Potential Sediment Parameters (Continued)

Parameter	Monitoring Program	Objective or Guideline	Rationale
Nonylphenols & Nonylphenol Ethoxylates	F,B	CCME/BC Working	Present in wastewater, possibly in agricultural runoff
Polychlorinated Biphenyls	F,[B]	BB Objective	Can enter bay via rivers
Organochlorine Pesticides	F,[B]	CCME/BC Working	Associated with agricultural runoff
Dioxins and Furans	F,[B]	CCME/BC Working	Unlikely in Boundary Bay
Polybrominated Diphenyl Ethers	[F],B	--	Emerging concern
Estradiols and Sterols	[F],B	--	Measured in other ambient monitoring programs
Chlorobenzenes	--	--	Unlikely in Boundary Bay
Phthalate Esters	--	--	Ubiquitous, samples easily contaminated

F – Fraser River, B – Burrard Inlet

[ ] - Analyzed but not necessarily recommended for ongoing monitoring



# Recommended Sediment Parameters

Particle Size

Moisture

Total Sulphide

Total Organic Carbon

Total Organic Nitrogen

Fecal Coliforms

Total Metals

AVS & SEM

Polycyclic Aromatic Hydrocarbons

Polychlorinated Biphenyls

Organochlorine Pesticides \*

\* Other classes of pesticides will be considered

# Recommended Sediment Parameters (Analyze if budget available)

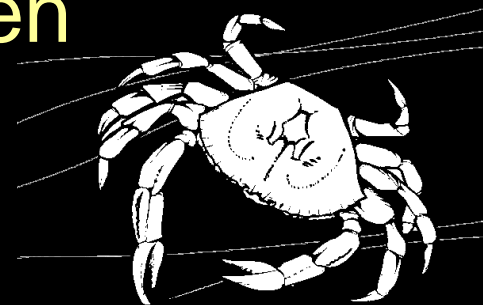
Nonylphenol & Nonylphenol Ethoxylates  
Alkylated PAHs  
Dioxins and Furans  
Polybrominated Diphenyl Ethers  
Estradiols and Sterols

# Biota Component



# Considerations

- What is an appropriate indicator for Boundary Bay?
- Potential Indicators
  - Fish Health & Tissue Chemistry
  - Benthic Invertebrate Community
- Availability of sentinel species
- Appropriate parameters for chosen indicator(s)

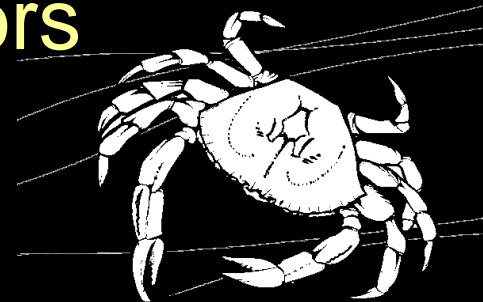




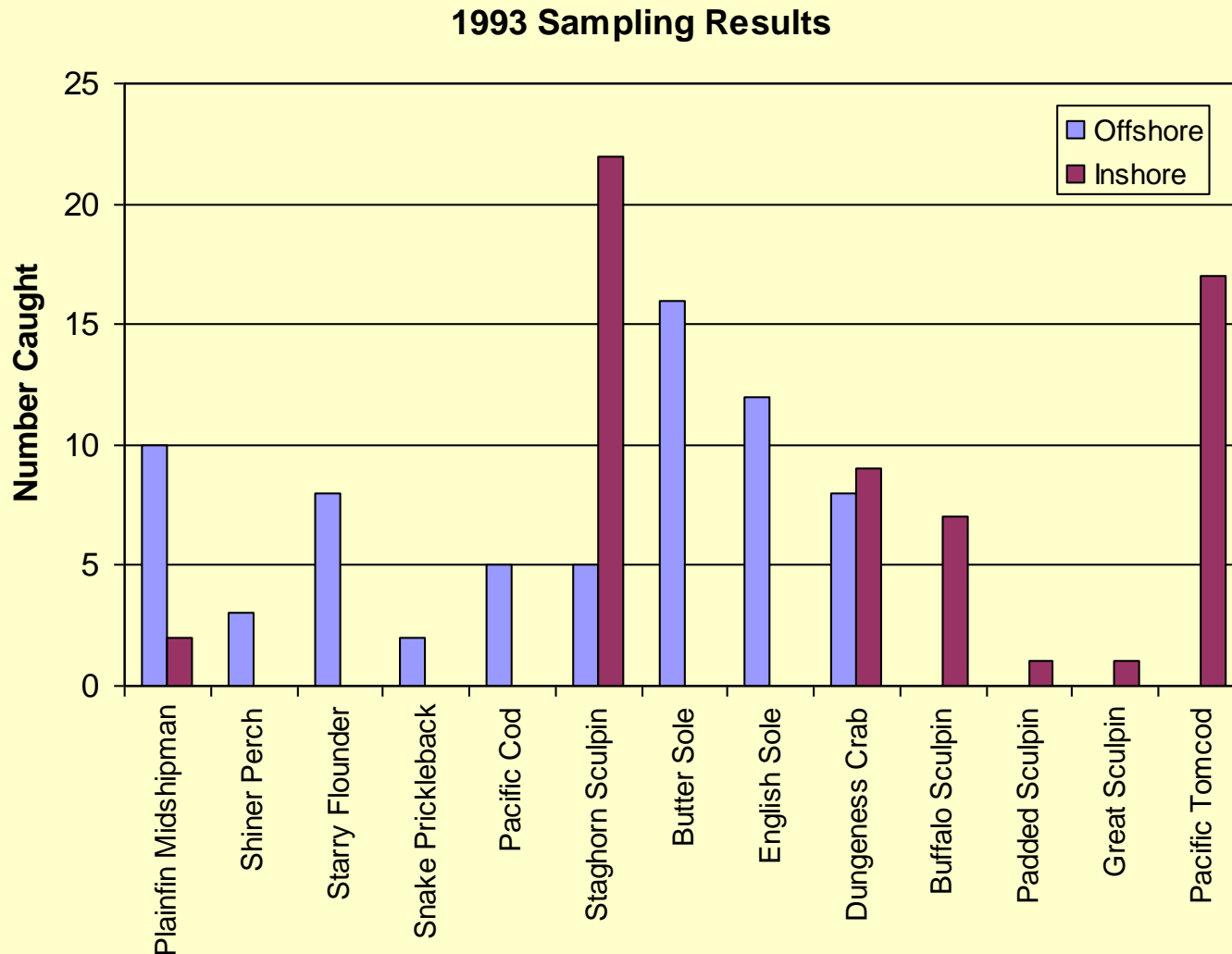
# “Fish” Health & Tissue Chemistry

## Desired Characteristics of Sentinel Species

- Abundant throughout Boundary Bay
- Sedentary or moves within a relatively confined home range
- Used in Metro Vancouver, Puget Sound and/or other monitoring programs
- Previously monitored in Boundary Bay
- Recognized set of health indicators for the species



# Fish Species Present (1993 Boundary Bay Trawl Results)



# Potential Sentinel Species

Species	Advantages	Disadvantages	Potential Use in Boundary Bay
English sole	Used for Burrard Inlet & Puget Sound Ambient Monitoring Programs Tissue data available for Boundary Bay	Not caught at inshore trawl station Highly mobile	No
Starry flounder	Tissue data available for Boundary Bay Used for 1998 Fraser River fish health study	Not caught at inshore trawl station Highly mobile	No
Staghorn sculpin	Tissue data available for Boundary Bay Present in inshore & offshore trawls Tissues used for Puget Sound Ambient Monitoring Program Likely moves less than many fish species	Move seasonally between inshore and offshore Young juveniles may move into rivers Not used for local fish health studies	Yes
Dungeness crab	Used for Puget Sound Ambient Monitoring Program Tissue data available for Boundary Bay Likely moves less than most fish species	Difficult or impossible to age Males & females may not occur at the same location outside the breeding season	Yes
Bivalves (various species: <i>Mya arenaria</i> , <i>Clinocardium nuttallii</i> , <i>Tresus capax</i> , others)	Worldwide use for tissue contaminant monitoring Tissue data available for Boundary Bay Sedentary Various health parameters tested in eastern Canada	Species abundances and distributions in Boundary Bay unclear Species (except mussels) not used for local "fish" health studies <i>C. nuttallii</i> is hermaphroditic	Yes, but not <i>C. nuttallii</i>

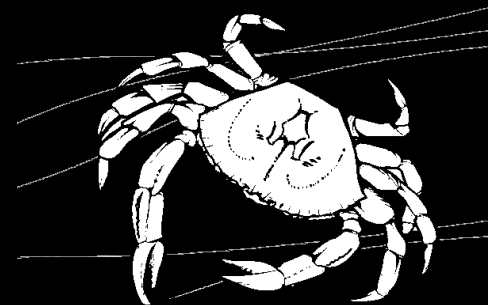
# Benthic Invertebrate Community

Advantages	Disadvantages
<p data-bbox="42 386 888 515">Abundant throughout Boundary Bay</p> <p data-bbox="42 644 927 772">Many species sedentary or move short distances (as adults)</p> <p data-bbox="42 822 915 1029">Some monitoring has been done in Boundary Bay (intertidal zone only)</p>	<p data-bbox="981 386 1875 586">Species composition varies with substrate: expect differences between sandy and muddy areas</p> <p data-bbox="981 644 1841 772">Species composition varies with depth</p> <p data-bbox="981 822 1841 1029">Species composition varies with salinity (possible effect of estuarine gradient)</p> <p data-bbox="981 1065 1686 1193">No information on subtidal community</p>



# Recommended Biota Indicators (Tentative)

- Fish tissue & fish health survey
- Two subtidal sentinel species:
  - Staghorn Sculpin
  - Dungeness crab
- One intertidal sentinel species: a bivalve (e.g. *Mya arenaria*)
- Consider adding a benthic invertebrate survey (intertidal)



# Potential Tissue Parameters

Parameter	Monitoring Program	Objective or Guideline	Rationale
Metals	F,B	<sup>1</sup>	Potential for bioaccumulation & presence in Boundary Bay
Organochlorine Pesticides	F,[B]	CCME	
Dioxins & Furans	F,[B]	CCME	Unlikely in Boundary Bay
PCB	F,B	BC Approved	Potential for bioaccumulation Sediment quality objective
PBDE	[F],[B]	--	Potential for bioaccumulation Emerging concern
Benzo[a]pyrene	[F],[B]	BC Approved	Metabolites in bile is a more effective indicator in fish
Chlorinated Phenolics	[F]	BC Approved <sup>2</sup>	Unlikely in Boundary Bay
Chlorobenzene	--	--	Unlikely in Boundary Bay
PAH Metabolites in Bile	B	--	Indicator of PAH Exposure

F – Fraser River, B – Burrard Inlet

[ ] - Analyzed but not necessarily recommended for ongoing monitoring

<sup>1</sup> Approved BC guidelines for Hg & Pb, Health Canada guidelines for As, Hg & Pb

<sup>2</sup> Approved BC guidelines relate to taste impairment.

# Potential Health Parameters

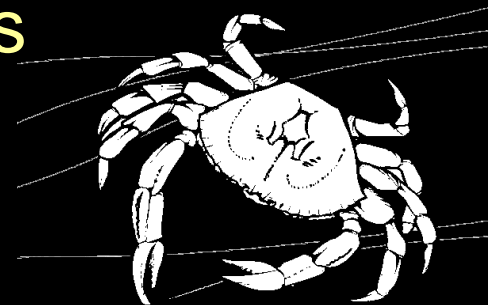
Parameter	Monitoring Program	Objective or Guideline	Rationale
Length, weight, tissue weight, age	F,B	--	Easily measured, can be useful effects indicators
Health Assessment Index	--	--	Used for Pulp & Paper EEM, highly subjective
Lipid reserves	F,B	--	Indicator of condition, affects accumulation of organic contaminants
Histopathology	B	--	Indicator of adverse effects, particularly from PAHs
Vitellogenin	B	--	Indicator of exposure to endocrine disruptors
Enzyme induction (CYP1A)	B	--	Indicator of exposure to PCBs
Metallothionein	--	--	Indicator of exposure to metals
By-Catch Enumeration	F	--	Provides some information on fish community

F – Fraser River, B – Burrard Inlet



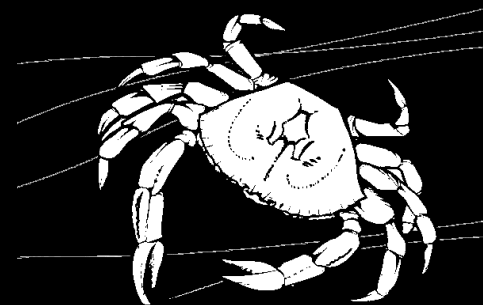
# Recommended Tissue Parameters

- Analyze in all samples
  - Metals
  - Pesticides (Organochlorine, possibly others)
  - PCB
- Analyze if budget available
  - Dioxins & Furans
  - Polybrominated Diphenyl Ethers
  - Benzo[a]pyrene or PAH Metabolites in Bile or Haemolymph



# Recommended Health Parameters

- Analyze in all samples
  - Length, weight, gonad & liver or hepatopancreas weight, age
  - Lipid reserves
- Analyze if budget available
  - Histopathology (fish liver)
  - Vitellogenin
- Additional Recommendation:
  - By-Catch Enumeration

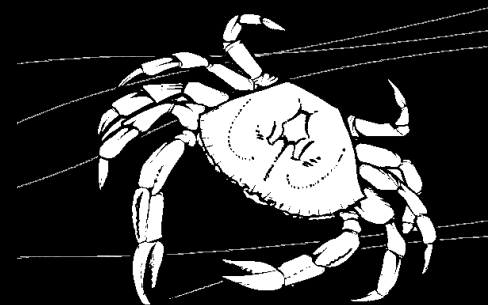


# Design Details



# Water Sampling

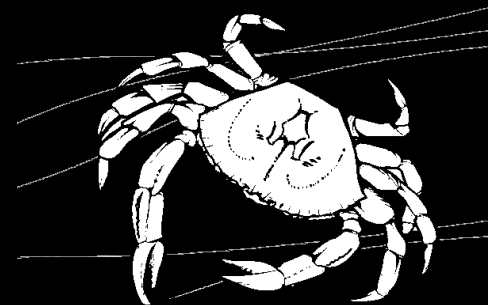
- Sample in November when runoff is highest
- Sample at rising tide/high tide to facilitate access and capture maximum seawater influence in estuarine area (does not apply to offshore sites)
- Collect one sample at mid-depth





# Sediment Sampling

- Collect samples in March or April after the period of highest runoff, when the maximum accumulation of contaminants in sediment is likely
- Sample intertidal areas at high tide
- Prepare composite replicate samples from 3 grabs
- Collect 3 replicate composite samples per site



# Biota Sampling

- Collect fish and crabs in November when runoff is highest
- Collect bivalves and/or benthic invertebrates (sediment infauna) in March or April, when sediments are sampled
- Collection methods will depend on species and location; various methods are acceptable

